PC Velocity Encoding: Temporal Characteristics of 1-sided, 2-sided non-SVE, and 2-sided SVE

J. Bender[1,2], Y. Ding[2], Y-C. Chung[3], S. Ramen[4], and O. Simonetti[2,5]

[1]Biomedical Engineering, The Ohio State University, Columbus, OH, United States, [2]Dorothy M. Davis Heart & Lung Research Institute, The Ohio State University, Columbus, OH, United States, [3]Siemens Medical Systems, Inc, Malvern, PA, United States, [4]The Ohio State University, Dorothy M. Davis Heart & Lung Research Institute, Columbus, OH, United States, [5]The Ohio State University, Biomedical Engineering, Columbus, OH, United States

Introduction: Low temporal resolution is an unsolved problem for phase contrast MRI (PC-MRI) peak valvular velocity quantification. Peak velocity is clinically important in quantifying valvular stenosis. Aortic and pulmonary valve imaging requires higher temporal resolution due to the intrinsically sharper velocity waveforms seen in these valves, especially in the presence of stenosis. Temporal resolution in PC-MRI is reduced by the need to determine the static background phase. This requires two k-space data sets to be captured for each reconstructed frame. A shared velocity encoding (SVE) was recently proposed [1]. This method shares 2-sided (balanced encoding with a positive and negative encoding) velocity encodings over time to improve temporal resolution. Theoretical analysis and simulation were used to compare the 2-sided SVE with 2-sided non-SVE and 1-sided (simple encoding with a velocity sensitive and compensated encoding) velocity encoding. SVE cannot be applied to 1-sided encoding since there is no velocity information in the velocity compensated data set.

Methods: Theoretical aspects of the three methods were explored. A computer simulation was preformed using a simulated velocity waveform. A half sine wave with duration 300ms was used with complete k-space sampling of 50ms. The underestimation of peak velocity due to sampling window length and frame rate was quantified. Due to an unknown registration between acquisition and the velocity waveform, the entire range of possible registrations time offsets were simulated (Figure 1).

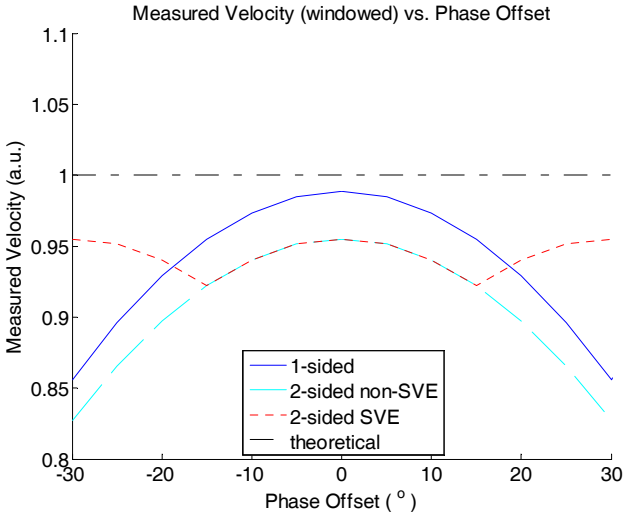

Figure 1: Measured peak velocity over range of misregistration offsets.

Results: Theoretical analysis showed that SVE has sampling window equal to 2-sided encoding without SVE, and twice as long as 1-sided encoding. SVE has a frame-rate twice as high as both non-SVE and 1-sided. Simulation shows that for good registration, 1-sided performs the best due to its short sampling window, but for greater misregistrations SVE is superior due to its higher frame rate. Non-SVE always has equal or poorer performance. The mean underestimation was calculated to be 5.59%, 8.81%, and 5.59% for 1-sided, non-SVE and SVE respectively.

Discussion: The velocity encoding method (1-sided or 2-sided) and reconstruction sharing (non-SVE or SVE) is the choice of the pulse sequence designer. Two-sided non-SVE offers no advantages over 1-sided acquisition or SVE reconstruction due to its longer sampling window and lower frame rate. SVE and 1-sided equally underestimate mean peak velocity. SVE's performance comes from its higher frame rate while 1-sided's performance comes from a shorter sampling window length. Either technique could be chosen to minimize peak velocity underestimation; SVE, however, has the advantage of reduced variation over the range of temporal registration, permitting better beat-to-beat evaluation of peak velocity variation. With less variation introduced by SVE, physiological variations can be easily distinguished.

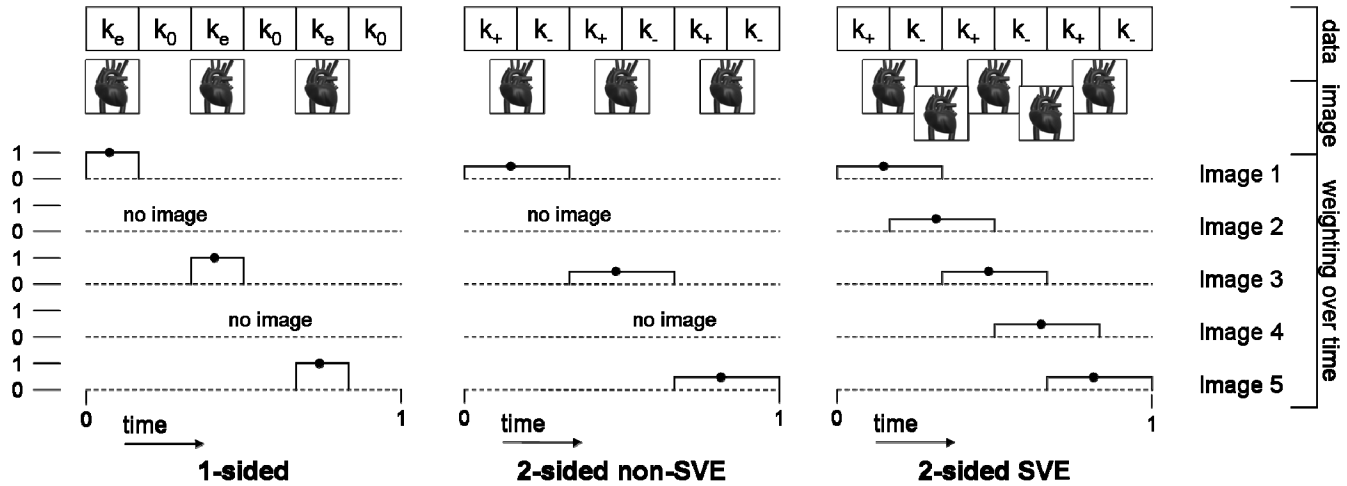

Figure 2: Velocity information weighting over time for 1-sided encoding, 2-sided encoding without SVE, and 2-sided with SVE.

[1] Hung-Yu Lin1, Yu Ding1, YiuCho Chung2 and Orlando Simonetti. *Shared velocity encoding (SVE): a new method for real-time velocity measurement with high temporal resolution.* Journal of Cardiovascular Magnetic Resonance 2009, 11(Suppl 1):O81